Design Guidelines for Underfloor Plenums

...
**Supply plenum**  
- Supply plenum  
- Ice stem exit  

**Return plenum**  
- Return plenum  
- Ice stem return  

**Thermal Performance of Underfloor Plenums**

**Laboratory research and field measurements**  
- Laboratory research and field measurements show that underfloor plenums can be significantly, especially in many buildings. Figure 2 shows how heat is transferred into underfloor plenums. Figure 4 shows the relative temperature gains for various underfloor plenums. The data points indicate the availability of underfloor fan termination units, which often are used to facilitate the design and installation of the system. The upper limit is an arbitrary response to various building codes.

**FIGURE 1:** Underfloor supply plenum layout.

**FIGURE 2:** Underfloor supply plenum temperatures measured as a function of environment, Due, after heating at 7 pm on Dec 22. The maximum temperature difference is 5°F.
requiring additional diagonal bracing for mid-floor installations exceeding 10 k. Over the range of plenum heights, air velocities are exceptionally low, except near ribs.

**Room cooling load distribution.** In a recent study, CRE investigated the primary pathways through which heat is removed from a room with DUEB. Room-air stratification produces higher ceiling-level temperatures, which change the dynamic of heat transfer within a room and between zones. Under typical operating conditions of a stratified UHAC system, heat is removed from a room through two paths:

- **Direct air exchange via room return air existing at ceiling level.**
- **Air exchange through the underfloor supply plenums by convection through the plenums and return plenums.**

Regulating mid-storied buildings, the major conclusion from the CRE study was:

- With unbalanced slab (current practice), approximately 30 to 40 percent of total room cooling load will be transferred into a supply plenum, while only 10 to 15 percent will be conveyed by return air extraction. The grate size and distribution will depend on the degree of stratification in the space.

The study also concluded that the convection path to the return plenums will be transferred into a supply plenum, with 30 to 40 percent accounted for by return air extraction, depending on the amount of stratification in the room.

- **With a balanced slab type B.30 as shown in Figure 5.2, the cooling load will be transferred into a supply plenum, with 70 to 80 percent accounted for by return air extraction, depending on the amount of stratification in the room.**

After returning the cooling load is calculated, it is recommended that the above guide be used as an approximation to the load between the underfloor plenums and the return plenums. These quantities will have a direct impact on the term-by-term cooling load in the underfloor supply plenum, as well as the room design air-cooling requirement.

As defined above, heat transfer into an underfloor plenum can be subdivided into a primary building. While the delivery of air through the underfloor plenum can be both reliable and efficient, the return of air from the plenum requires a primary building.

- **Primary plenum heat gains and plenum airflow requirements.** For functional design purposes, the temperature of air supplied to a room is assumed to be 65°F. This allows the calculation of the temperature of supply air required from an air-handling unit. Primary plenum heat gains should be included in calculating the required flow of air, a weighted average of inter-storey plenum and return plenum temperatures impacting the plenum zone. For example, a 50 ft long plenum zone with the same 55°F representing the primary zone would apply: 75 percent and 25 percent of the inter-storey and return plenum heat load, respectively. Application of the total delivered peak airflow offshore that plenum zone is recommended. If a zone covers both interstorey and return plenum areas, a weighted average of both of those airflow rates should be applied. The percent load on the plenum is taken from the load fractions described above.

With this information, average plenum temperate gains can be calculated:

$$\Delta T_{\text{plenum}} = \frac{Q_{\text{plenum}}}{G_{\text{air}}}$$

where:

- $$\Delta T_{\text{plenum}}$$ in degrees Fahrenheit
- $$Q_{\text{plenum}}$$ in watts per square foot
- $$G_{\text{air}}$$ in cubic feet per minute per square foot

From this result, the plenum inlet temperature (plenum inlet temperature required to maintain a specified supply temperature of 68°F can be calculated as follows:

$$T_{\text{inlet}} = T_{\text{return}} - \Delta T_{\text{plenum}}$$

Note that while $$\Delta T_{\text{plenum}}$$ represents temperature gains across the entire area of the plenum, maximum air temperatures inside the plenum can be well above 68°F.

**Plenum temperature variations.** Extensive research by CRE demonstrates that plenum air temperatures may vary by both width and length throughout a floor plane, depending on many factors. The combined effect of those factors on plenum temperature distribution is difficult to profile. The following guidance is provided to help estimate variation in temperature:

- **Plenum air temperature variation, which can cause high-speed jet and large recirculating plenum airflow within a plenum. Higher airflow velocities increase the rate of heat transfer between plenum air and a slab and floor panels.**

- **Although research confirms, evidence suggests temperature variation can be limited by reducing plenum inlet velocities and spreading airflow across primary through the plenum.** Such plenums use plenum airflow with green filling delivery characteristics (Figure 5.3).

- **If the building design allows 3.5 air changes per hour in a return plenum, air inlet to the return plenum requires the return plenum to be designed to deliver air at a lower reserve temperature.**

- **Because of the complexity of plenum airflow and heat transfer, the use of computational fluid dynamics (CFD) simulations (Figure 5.5) for plenum design may be advisable.**

- **Maintain current methods of controlling temperature variations include adding dampers in return air supply for air further...**
Air photo. The use of air highways—defined as any route or other plane—distributes energy through parts of the plane where the plane is not too large and contains temperatures below the plane. If the plane has a temperature less than 1.5°C, the plane is not too large and does not contain temperatures above 10°C. A simplified two-dimensional heat balance model was used to investigate the plane's performance. The following was obtained: temperature as a function of the plane, 62°F plane air temperature, 69°F plane air temperature, and 75°F plane air temperature. Operation Table 1 summarizes the plane's performance. Temperature at the end of the air highway was measured at 69°F plane air temperature. Temperature at the end of the air highway was measured at 69°F plane air temperature.
down one-third of total room cooling load. This finding has important implications for the design and operation of USASH systems, including variation of design cooling airflow quantities and plenum air temperatures.

Guidance for reducing plenum temperature variations through a variety of techniques, including well-designed plenum-side conditions, the location of return air openings, plenum return air plenum partitions, and plenum ventilation, was given, or was guidance for the reduction of plenum heat gain for class-A grades, general air plenums and the use of air highways in underfloor plenums.

ACKNOWLEDGMENTS

The authors wish to acknowledge the support of CRI partner Armstrong World Industries, Arg, the California Department of General Services, the California Energy Commission, Charles M. Saker Associates Inc., Cheh & Koo, FHK, Pacific Gas & Electric Co., Pace Industries, ETI, Inc., Association Inc., Skidmore Owings and Merrill, Siemens, Skidmore Inc., Skala Rommey Group, Tate Access Floors Inc., the Taylor Engineering Team (Tate Engineering), The Electrical Contractor, Gannett Fleming, Northwest Concrete Industries, S.J. Bovard & Associates, The National Association of Energy, the U.S. General Services Administration, Whalen Hallock, York International, the National Science Foundation, and The Regents of the University of California.

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